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Regular and irregular shaped isolated domains in uniaxial ferroelectrics

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The variety of domains shapes appeared in uniaxial ferroelectrics will be presented, classified and described systematically. The obtained experimental results will be discussed using unified kinetic approach based on the analogy between domain structure evolution and phase growth during first-order phase transformation.

The classical theoretical approach predicted only the regular polygonal shape of isolated domains defined by crystal symmetry [1,2]. Recent systematic experimental study of the domain shapes allowed revealing wide shape variety which can be divided into: (i) circular shapes, (ii) regular polygons, (iii) irregular polygons, (iv) irregular shapes. The kinetic approach to domain growth based on generation of steps (pairs of kinks) and kink motion has been used for explanation of all obtained results [3]. The nucleation probabilities are determined by the local value of the sum of the applied field and residual depolarization field at the domain wall.

The crucial role of the bulk screening retardation in domain growth is demonstrated. The domain shape complication due to screening ineffectiveness was demonstrated experimentally and by computer simulation [3]. Two limiting mechanisms of the step nucleation have been considered: (a) stochastic with equiprobable position of nucleation sites, (b) determined with step generation at fixed points and anisotropic kink motion.

Stochastic nucleation leads to formation of the circular domains, whereas determined one stimulates formation of the polygonal shapes. The convex polygons with walls parallel to the main crystallographic axis appeared for effective screening: (a) hexagons for C_{3v} symmetry (lithium niobate, lithium tantalate and lead germanate), (b) squares for C_4 symmetry, (strontium-barium niobate), (c) rectangles for C_2 symmetry (potassium titanyl phosphate [4]). Obtained domain shape stability effect (fast restoration of the initial concave polygonal shapes after domain merging) was attributed to formation of the short-lived super-mobile walls [5]. It was demonstrated that polygons and stars with concave angles can appear as a result of screening retardation only [6].

The stochastic nucleation at the elevated temperatures leads to lack of the domain shape stability thus opens the way to complicated fractal and dendrite domain shapes [7,8]. The dendrite (snowflakes) domain structures can be created by: (i) discrete switching with subsequent merging, (ii) domain shrinkage under the action of the pyroelectric field or spontaneous backswitching, (iii) domain growth at the elevated temperatures in the plates with artificial dielectric layer [9].

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